Modeling and Control Software Tools to Support V2G Integration

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(On behalf of the Multi-Lab EV Smart Grid Working Group)

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Project ID: VS183

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Multi-Lab EV Smart Grid Working Group
(Convened by the DOE Vehicle Technologies Office)

Overview

Timeline

- April 1, 2016
- April 1, 2019
- Percent complete: 10%

Budget

- Total funding: $2.86M (DOE)
- FY16 funding: $970k (new start)

Partners

- Multi-Lab EV Smart Grid Working Group
  - Lawrence Berkeley National Lab (Project lead)
  - Argonne National Lab
  - Idaho National Lab
  - Oak Ridge National Lab
  - National Renewable Energy Lab
  - Pacific Northwest National Lab
- California Energy Commission, on behalf of the CA inter-agency VGI working group,

Barriers

- ***Feasibility of Vehicle-Grid Integration (VGI) remains unclear***
- **Distribution of *value available across multiple stakeholders* is uncertain**
- **Uncertain how effectively plug-in vehicles (PEVs) can *enable renewables integration***
- **Require tools for modeling and run-time controls for collections of vehicles**

Relevance and Project Objectives

Relevance

- **Grid services by plug-in vehicles can be valuable for drivers, OEMs, and grid stakeholders, while enabling grid integration of renewables**
  - Long-term opportunity:
    ~1,000 GWh of grid storage available if ¼ U.S. LDV are PHEVs

- **Feasibility (value, cost, complexity, and risks) of VGI remain unclear**
  - Unclear value across stakeholders is a barrier to deployment of VGI

Project Objectives

- **Quantify the *feasibility of VGI***
  - Determine the feasibility of VGI by quantifying *value, cost, complexity, and risks* of several VGI implementations
  - Quantify the *available value across stakeholders* of several VGI implementations
- **Quantify the ability for *vehicles to enable renewables integration***
  - Quantify the extent to which electrified vehicles can be an enabler for integration of intermittent renewable power generation
- Develop tools for modeling and run-time controls for collections of vehicles

Milestones

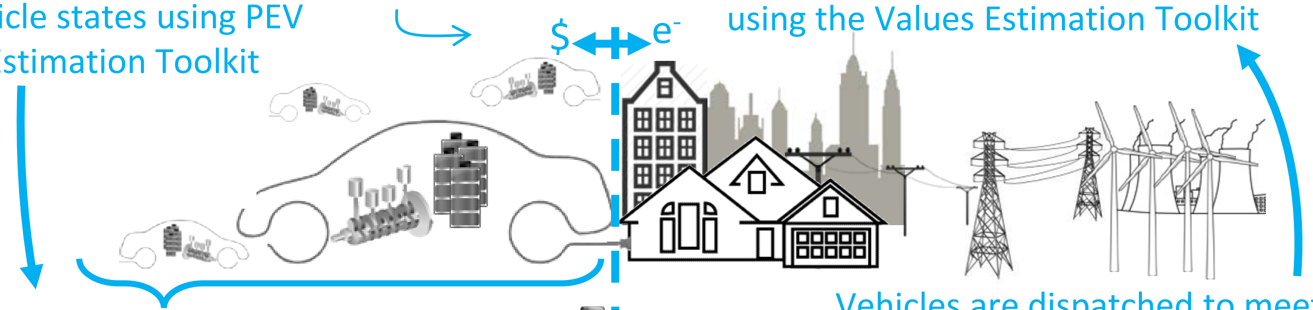
	Task 1: Development and Validation of VGISoft	Task 2: VGI Feasibility Assessment	Task 3: VGI Renewables Integration Assessment
Q1	➢ Finalize objectives /requirements of each VGISoft toolset ➢ Survey capabilities and methods to leverage from prior models ➢ Develop slide deck explaining VGISoft structure and plan for how it will be created	➢ List and categorize VGI implementation approaches to be explored for feasibility assessment	➢ List and categorize VGI implementation approaches for renewables integration to be explored for assessment
Q2	➢ Create and integrate codes to establish VGISoft architecture, data exchange standards, and variables structure ➢ Expand VGISoft slide deck to explain framework architecture.	➢ Prioritize VGI implementation approaches to be explored in feasibility assessment.	➢ Prioritize VGI renewables integration approaches to be explored.
Q3	➢ Create and integrate PEV Estimation, Capacity Allocation, Delivery Optimization, Resource Allocation Toolkits ➢ Expand VGISoft slide deck to explain all toolkit methodologies.		
Q4	➢ Create Values Estimation Toolkit within VGISoft ➢ Create model initialization, results post-processing, and results visualization tools ➢ Demonstrate complete VGISoft functionality ➢ Expand VGISoft slide deck with example results.	➢ Define simulation scenarios and initialization parameters for VGI feasibility assessment case studies.	➢ Define simulation scenarios and initialization parameters for VGI renewables integration assessment case studies.

Approach / Strategy

1) Integrate & release VGISoft co-simulation framework

Model N individual vehicle states using PEV Estimation Toolkit

Costs & values of delivered grid services are quantified using the Values Estimation Toolkit



VGISoft

- PEV Estimation Toolkit
- Capacity Availability Toolkit
- Delivery Optimization Toolkit
- Resource Allocation Toolkit
- Values Estimation Toolkit

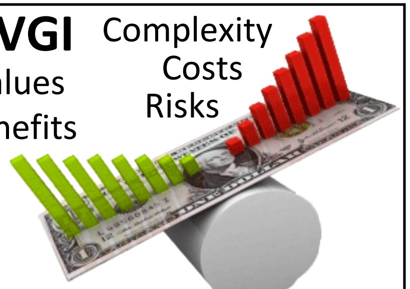
Vehicles are dispatched to meet grid service commitments using real-time Resource Allocation Toolkit

Vehicle forecasts and states inform aggregator virtual battery models for VGI using Capacity Availability Toolkit

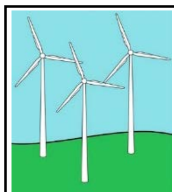
Aggregator determines grid services to offer from virtual battery flexibility to maximize benefits, makes commitments ahead of service interval using the Delivery Optimization Toolkit

2) Apply VGISoft in case studies to address critical knowledge gaps

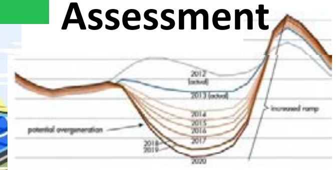
VGI Values Benefits — Complexity Costs Risks

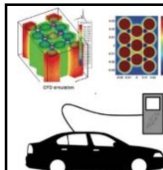


Feasibility Assessment

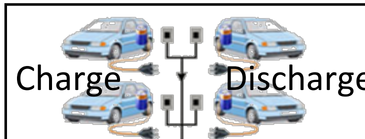


VGI Renewables Integration Assessment





Assess Battery Health Impacts of VGI

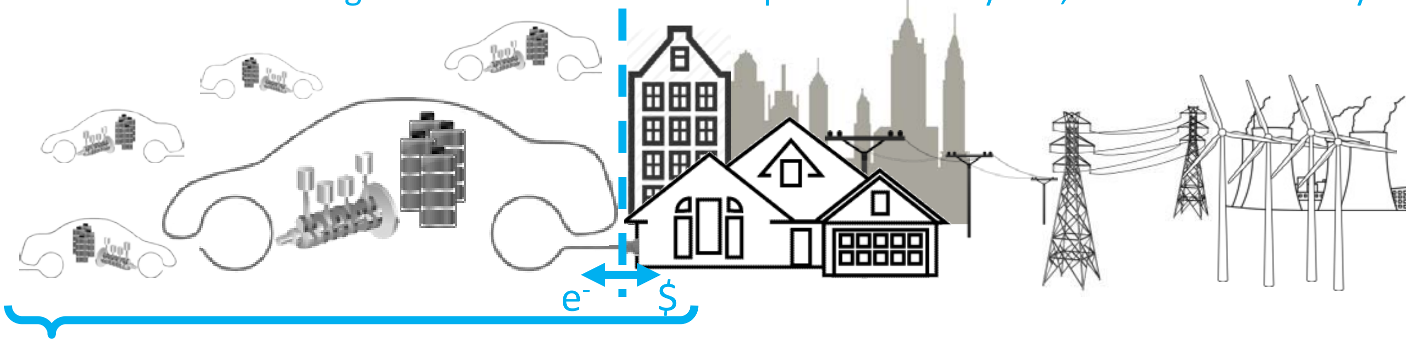


Real-time Resource Scheduling

Technical Accomplishments and Progress

Vehicle-to-Grid Simulator (V2G-Sim)

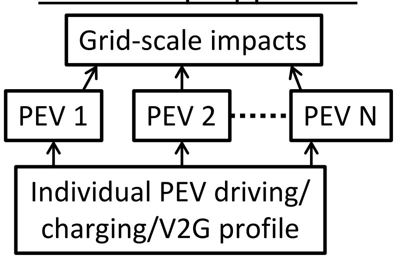
Vehicle and vehicle-grid simulation code developed at Berkeley Lab, available for use by all stakeholders



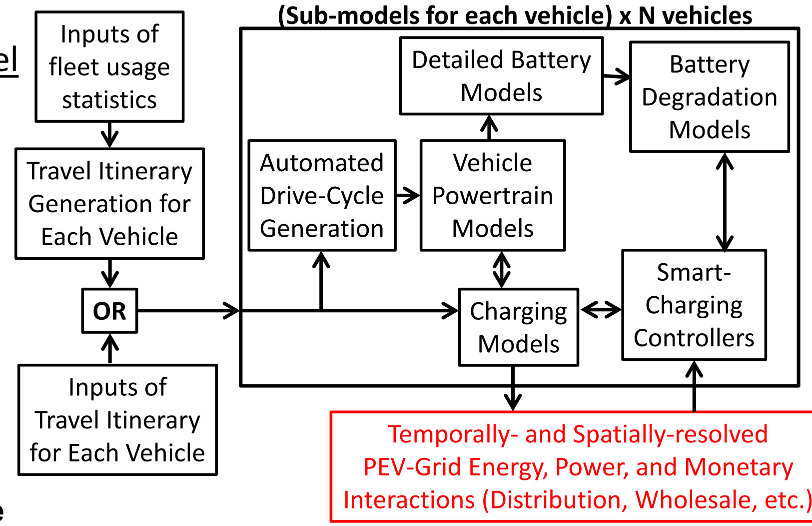
VGISoft will leverage methods from several DOE simulation tools, including V2G-Sim

V2G-Sim models the driving & charging of many individual vehicles to temporally & spatially predict how vehicles can benefit the electricity grid and how the grid will affect vehicles

V2G-Sim follows a Bottom-up Approach



V2G-Sim Model Architecture



Includes libraries of models of varying complexity & computing time

Core objective: a platform to develop and test any user-defined charge/discharge control approach and co-simulate with complementary models (e.g. distribution, transmission, market, etc.)

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FY15 – Applying smart charging on forecasted future California net load

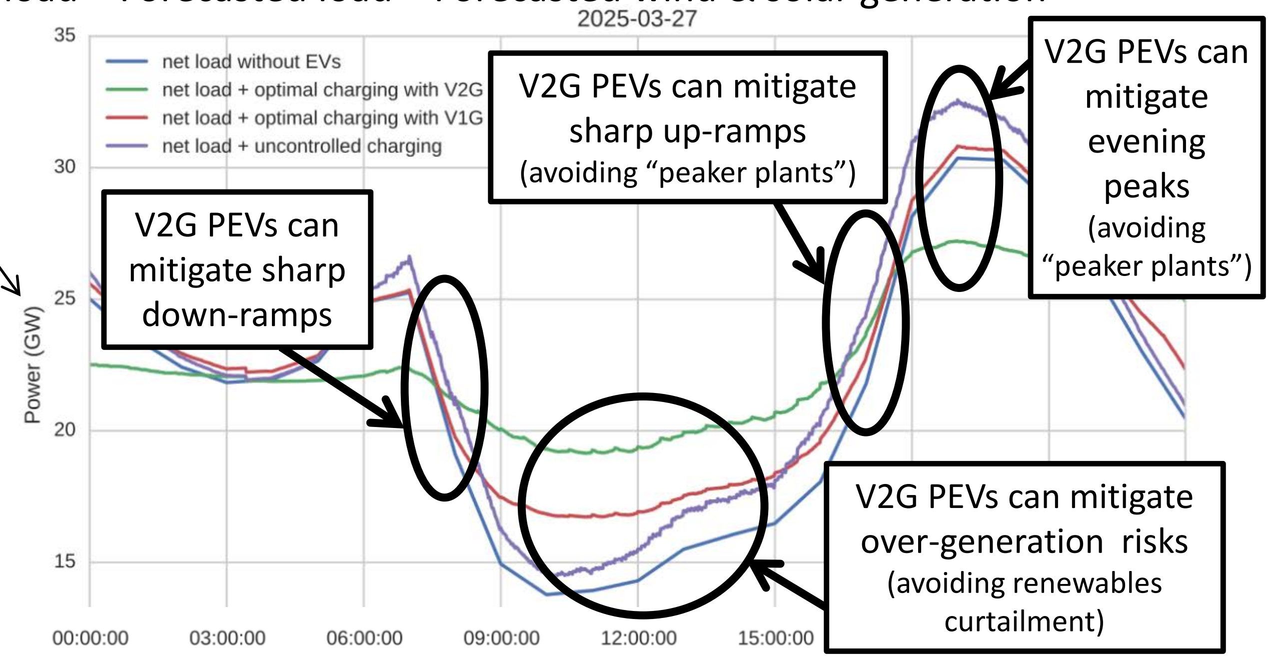
Scenario:

- 3 millions electric vehicles (24kWh battery)
- Charging stations at home and work (7.2kW)
- 2009 NHTS travel itineraries for California drivers

** V1G only allows power to flow from the grid to vehicles*
** V2G allows bi-directional power flow between vehicles and the grid*
**Optimal charging to smooth the net load*

California net load forecast for a possible day in 2025

Net load = Forecasted load – Forecasted wind & solar generation



- Uncontrolled charging will ***increase the peak power*** around 6pm
- V2G with optimal charge control ***mitigates 4 major challenges of substantial renewables***
- V1G with optimal charge control ***reduces over-generation without worsening evening peak***

FY15 - Quantifying EV Battery Degradation from Driving vs. V2G Services

Factors influencing battery degradation:

1. Temperature
2. Charge Rate
3. Depth of Discharge
4. Time

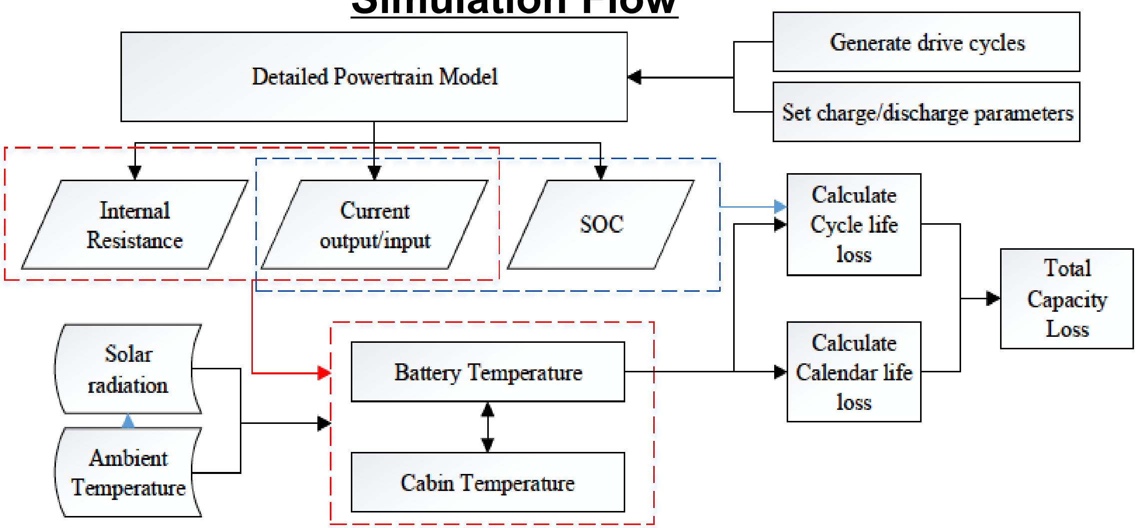
Many possible degradation models can be leveraged in VGI simulations, one example:

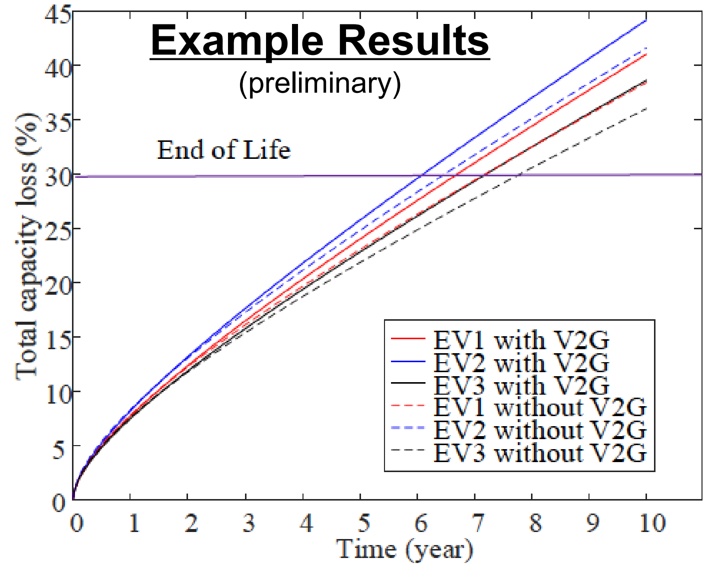
$$Q_{loss}^{total} = (a \cdot T^2 + b \cdot T + c)e^{(d \cdot T + e) \cdot I_{rate}} \cdot A_h + f \cdot e^{-E_a/RT} \cdot t^{1/2}$$

Capacity loss caused by cycling

Capacity loss caused by calendar aging

Simulation Flow

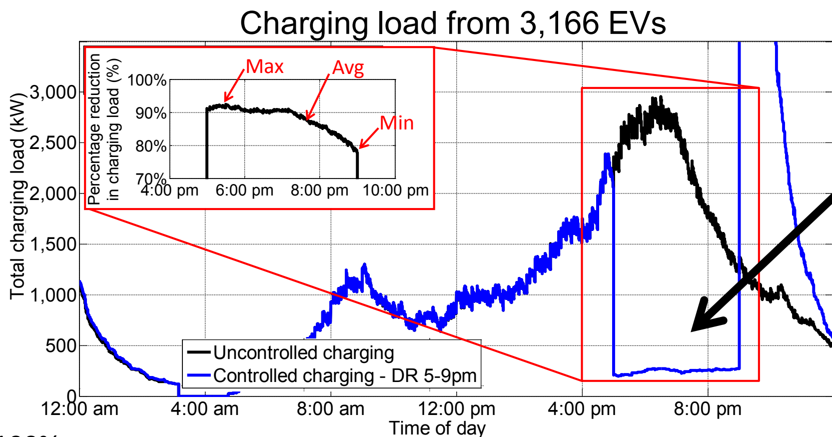




Battery degradation over ten years

Technical Accomplishments and Progress

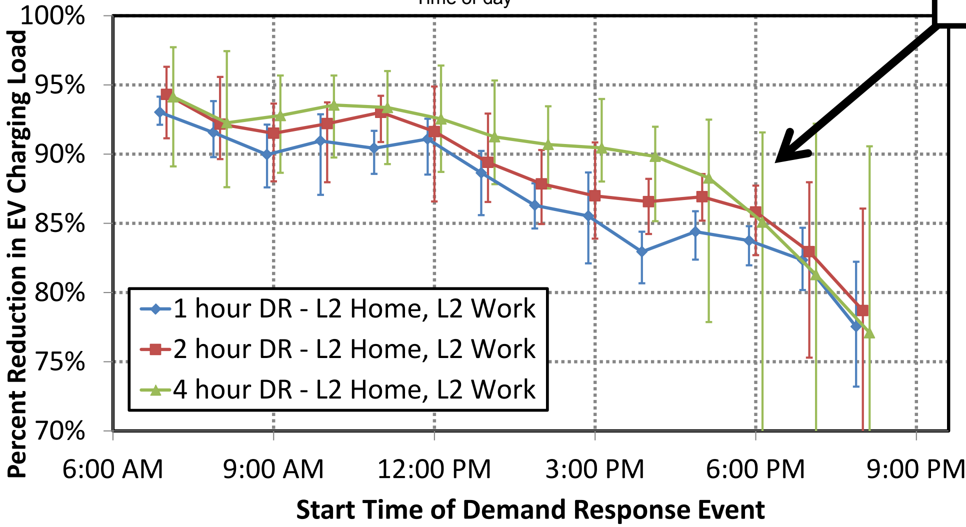
FY15 - Quantifying the Flexibility for EVs to Offer Demand Response (DR)



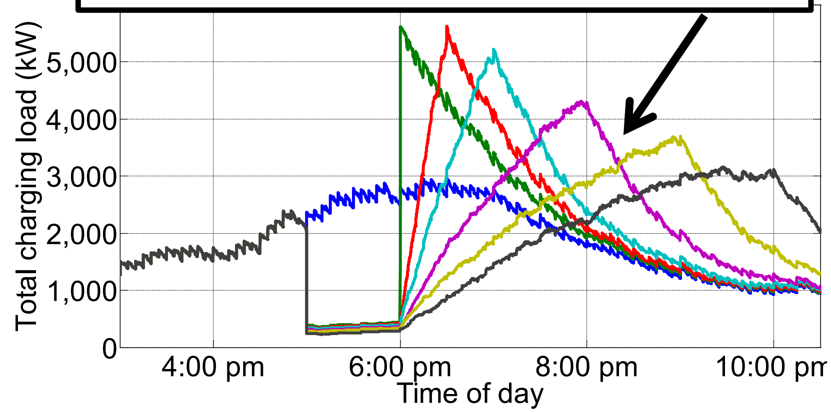
Managed charging controller in VGISoft reduces PEV charging during DR events
(without interfering with any drivers' mobility needs)

Parametrically simulate DR events for different durations, at different times of day

75-95% EV charging can be shed during DR event without interfering with driver needs



Can mitigate post-DR peak by gradually resuming EV charging



S. Saxena, et al., SAE 2015-01-0304

Response to Previous Year Reviewers' Comments

- Project not reviewed last year, project is a new start

Collaborations

Multi-Lab EV Smart Grid Working Group
(Convened by the DOE Vehicle Technologies Office)

↓

Integrating VGISoft co-simulation framework

↓ (Efforts occur in parallel) ↑

Application of VGISoft across targeted case studies, leveraging real-time aggregator systems

- VGI Feasibility Assessment
- VGI Renewables Integration Assessment
- VGI Battery Health Impacts
- Real-time Resource Scheduling

(Application of findings to accelerate VGI deployment) ↓ ↑ (Guide research questions, case study investigations, and VGI implementations)

Stakeholder advisory team

California Inter-Agency VGI Working Group
(point of contact: California Energy Commission)

Additional stakeholder advisors
(outreach in process)

E.g., Utilities, Automotive OEMs, EVSE Mfgs, Aggregation Entities, System Operators, Multi-state ZEV MOU members

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Key Challenges and Proposed Future Work

Key Challenges

(in integrating toolkits into VGISoft)

- Integrating sub-models and real-time controllers across multiple temporal and spatial scales
- Integrating sub-models that adequately account for real-world constraints to aggregated vehicle-grid services (e.g. communications delays, sensor noise, uncertainties)
- Preserving adequate flexibility in frameworks to account for a variety of costs associated with VGI (e.g. risks of failure to provide awarded grid services, battery degradation, market transaction costs, etc.)

Future Work

(for project Year 1)

1) Integrate & release VGISoft co-simulation framework

VGISoft

PEV Estimation Toolkit
Capacity Availability Toolkit
Delivery Optimization Toolkit
Resource Allocation Toolkit
Values Estimation Toolkit

- Integration of existing simulation tools / methodologies into VGISoft framework, development of new sub-models and controllers where necessary

2) Specific definition of parameters for case studies

- Broad categories of case studies have been defined, with focus on VGI feasibility assessment and renewables integration assessment
- Further case study definition from stakeholder input:
  - Temporal and spatial scales of greatest interest for each case study category
  - Sensing, communication, and control approaches of greatest interest for vehicle and aggregator control systems

Summary

Relevance

- **Plug-in vehicles can become an enabler for grid integration of renewable energy, while providing value for all stakeholders**
- **Feasibility (value, cost, complexity, and risks) of VGI remain unclear**

Approach / Next Steps

- **Integrate and release VGISoft co-simulation framework**
- **Apply VGISoft towards targeted case studies**
  - VGI Feasibility Assessment
  - Renewables Integration Assessment
  - VGI Battery Health Impacts
  - Real-time Resource Scheduling

FY15 Technical Accomplishments

- **New start project,**
  building upon prior efforts from Multi-Lab EV Smart Grid Working Group
- **VGISoft will integrate capabilities from several DOE simulation tools,**
  including V2G-Sim, a 2015 R&D100 winner
- **Preliminary case study results:**
  - PEVs can play a substantial role in mitigating renewables intermittency (case study for CAISO wholesale market, duck curve)
  - Limited battery health impacts from V2G in comparison health impacts from driving only
  - EVs are *highly* flexible loads, >75% load shed available during demand response without affecting driver mobility needs